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Submitted to:  
Encana Oil & Gas (USA) Inc.  
Denver, Colorado

Submitted by:  
AECOM  
Fort Collins, Colorado  
60196941  
August 2012

# Pavillion Natural Gas Field, Fremont County, Wyoming, Encana Oil & Gas (USA) Inc.

## Remedial Alternatives Evaluation and Work Plan – WH Paul Patent 42x-11 Draft

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## List of Acronyms

AECOM	AECOM Technical Services, Inc.
AS	air sparge
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and total xylenes
COI	compound of interest
CY	cubic yard
DO	dissolved oxygen
DRO	diesel range organics
Encana	Encana Oil & Gas (USA), Inc.
ft/ft	feet per foot
GRO	gasoline range organics
GSR	green and sustainable remediation
HASP	Health and Safety Plan
IDW	investigation derived waste
K	hydraulic conductivity
LNAPL	light non-aqueous phase liquid
Mcf	thousand cubic feet
MCL	maximum contaminant level
MKTT	Mann-Kendall Trend Test
MNA	monitored natural attenuation
mg/L	milligrams per liter
mV	millivolt
OM&M	operation, monitoring, and maintenance
ORC	Oxygen Release Compound®
ORC-A	Oxygen Release Compound – Advanced ®
ORP	oxidation reduction potential
PID	photoionization detector
POP	Project Operating Procedure
RAE Report	Remedial Alternatives Evaluation Report
SHWD	Solid and Hazardous Waste Division
SVE	soil vapor extraction
SVOC	semi-volatile organic compound
TP	Tribal Pavillion

TPH	total petroleum hydrocarbons
UIC	Underground Injection Control Permit
USEPA	United States Environmental Protection Agency
VOC	volatile organic compound
VRP	Voluntary Remediation Program
WDEQ	Wyoming Department of Environmental Quality
WDNR	Wisconsin Department of Natural Resources
WQD	Water Quality Division

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## 1.0 Introduction

This Remedial Alternatives Evaluation (RAE) report has been prepared by AECOM Technical Services, Inc. (AECOM) on behalf of Encana Oil & Gas (USA) Inc. (Encana). The purpose of this report is to present an evaluation of remedial alternatives and select a remedial approach for the WH Paul Patent 42x-11 (also known as Tribal Pavillion 42x-11 [TP 42x-11]) well site (Site) in Fremont County, Wyoming. This RAE was prepared in accordance with the Wyoming Department of Environmental Quality (WDEQ) Voluntary Remediation Program (VRP) requirements and Fact Sheet #21. This document replaces the original RAE for the Site that was submitted to the WDEQ on August 31, 2010 (KC Harvey 2010). The activities described herein are to take place under the WDEQ VRP.

### 1.1 Summary of Objectives

The objectives of this RAE are as follows:

- Characterize Site conditions;
- Present data to document the complete removal of all petroleum hydrocarbon impacted soil that exceeded the WDEQ soil clean-up levels;
- Evaluate alternatives to remediate petroleum hydrocarbon impacts to groundwater at the Site;
- Select a remedial technology and approach to achieve groundwater clean-up levels at the Site; and
- Present a plan for remediation implementation, groundwater monitoring, and confirmation sampling for Site closure.

The objective of the remediation activities presented in this report is to reduce the concentrations of petroleum hydrocarbons in groundwater to below groundwater clean-up levels as defined in Section 4.1.

### 1.2 Site Description and History

The TP 42x-11 Site is located in Fremont County, Wyoming, approximately 4.5 miles east-northeast of the town of Pavillion, Wyoming, in the southeast 1/4 of the northeast 1/4 of Section 11, Township 3 North, Range 2 East. A Site location map is provided as **Figure 1-1**. The Site is located on privately owned property. The Site contains a gas well head, a production tank, separator units, former production pit area, and monitoring wells. The land surrounding the TP 42x-11 Site is used for agricultural purposes. The Site vicinity map is provided as **Figure 1-2**. The current Site plan is provided as **Figure 1-3**.

The TP 42x-11 gas well is in the Pavillion Field of the Wind River Basin in central Wyoming. The gas well is currently operated by Encana. The gas well was originally drilled in 1973 to a depth of 5,028 feet below ground surface (bgs). As of September 2010, the well has produced 170 barrels of water, and 5,957,887 thousand cubic feet (Mcf) of gas. The gas well is currently in production.

The Site was first investigated in 2006 and placed in the WDEQ VRP based on the initial investigation results. In September 2008, approximately 900 cubic yards (CY) of petroleum hydrocarbon impacted soil were removed from the Site (KC Harvey 2010). Soil samples collected from the excavation side walls and floor confirmed the removal of the petroleum hydrocarbon impacted soil below applicable clean-up levels (KC Harvey 2010).

Supplemental Site characterization was conducted in August and September 2011 along with quarterly (seasonal) groundwater monitoring from August 2011 through May 2012. The supplemental Site characterization activities were conducted based on an evaluation of existing characterization and remediation data, comments provided by the WDEQ (WDEQ 2010) concerning the 2010 RAE, and meeting discussions with the WDEQ. The work was implemented in accordance with the approved Supplemental Site Characterization Work Plan dated June 2011 (AECOM 2011; WDEQ 2011). The investigation focused on the vicinity of the previously excavated unlined production pit. The objectives of the supplemental Site characterization activities were to further characterize the soil and groundwater impacts at the Site and to obtain suitable Site specific information for determining appropriate remedial actions. The results obtained during implementation of the approved work plan are presented in Section 2.0.

### **1.3 Document Organization**

This document is divided into the following sections:

- Section 1.0 provides introductory information and objectives;
- Section 2.0 presents the results of the 2011 and 2012 supplemental Site characterization activities;
- Section 3.0 presents the Site characterization information;
- Section 4.0 describes the criteria for the remedial alternative evaluation;
- Section 5.0 identifies the development and evaluation of remediation alternatives;
- Section 6.0 presents the work plan for the selected alternative; and
- Section 7.0 lists references cited in this document.

## 2.0 Supplemental Site Characterization Results (2011 and 2012)

This section presents the results of the supplemental Site characterization activities that were implemented in 2011 and 2012.

### 2.1 Soil Assessment

Eight soil borings were drilled on August 25 and 28, 2011. The soil borings were located along the approximate perimeter of the 2008 pit excavation. Soil samples were screened in the field with a photoionization detector (PID). Evidence of vadose zone soil impacts was not observed in any of the soil borings. Soil boring locations from the August 2011 investigation are shown in **Figure 2-1**. Soil boring logs from the August investigation are provided in **Appendix A**. Soil sampling analytical and geotechnical laboratory reports are included in **Appendix B**. Soil sampling analytical results are summarized in **Table 2-1**.

### 2.2 Groundwater Assessment

One permanent groundwater monitoring well, MW-6, and one temporary groundwater monitoring well, WT-1, were installed during the August/September investigation activities. Five monitoring wells were already in place from prior investigation activities. Monitoring Well MW-6 was installed off-site to the south of the source area to determine the off-site extent of groundwater impacts. Temporary Monitoring Well WT-1 was installed within the area of previous soil remediation to provide information on the groundwater impacts within the source area. Monitoring Well MW-6 was installed on September 7, 2011 and developed on September 8, 2011. Temporary Monitoring Well WT-1 was installed on August 25, 2011, and developed on September 1, 2011. Groundwater samples were first collected from each monitoring well on September 9, 2011. The groundwater samples were laboratory analyzed for the following parameters:

- Benzene, toluene, ethylbenzene, and total xylenes (BTEX) using United States Environmental Protection Agency (USEPA) Method 8260B; and
- Total petroleum hydrocarbons as gasoline range organics (TPH-GRO) and diesel range organics (TPH-DRO) using USEPA Method 8015.

The monitoring well locations are shown in **Figure 2-1**. Soil boring logs and well construction details are provided in **Appendix A**. Groundwater sampling analytical reports are included in **Appendix B**. Groundwater sampling analytical results are summarized in **Table 2-2**.

Four complete rounds of groundwater monitoring were conducted to evaluate seasonal fluctuations in groundwater conditions. Groundwater sampling was conducted as follows:

- August 9, 2011: peak irrigation season;
- November 2, 2011: immediately following the irrigation season;
- January 27 and 28, 2012: non-irrigation season; and
- May 10, 2012: early irrigation season.

The groundwater sampling field forms are provided in **Appendix A**. Groundwater sampling analytical reports are included in **Appendix B**. Groundwater sampling analytical results are summarized in **Table 2-2**.

## 3.0 Site Characterization

This section presents the current Site conditions based on the information collected during previous investigation activities. Work completed includes soil boring and sampling, excavation, monitoring well installation, and groundwater monitoring activities.

### 3.1 Site Geology

The Site is underlain by Quaternary age alluvial sediment deposits. Based on field observations during a soil investigation conducted in 2011, the alluvial deposits consist of sand with gravel and silt, silt, sand with silt, silt with clay, and clay. A total of nine soil borings were advanced during the 2011 soil investigation. Cross sections have been developed based on the boring logs generated during the 2011 soil investigation. **Figure 3-1** is a cross section location map of the Site. Cross-section A-A' runs west to east along the northern portion of the previously excavated pit from soil boring SB-1-11 to SB-5-11. Cross-section A-A' is illustrated in **Figure 3-2**. Cross-section B-B' runs west to east along the southern boundary of the previously excavated pit from SB-2-11 to SB-5-11. Cross-section B-B' is illustrated in **Figure 3-3**. The cross sections indicate sand with gravel and minor silt near the surface. This is generally underlain by silt with sand or silt with clay across the Site. The water table is located approximately 5 to 7 feet bgs.

### 3.2 Site Hydrogeology

Groundwater beneath the Site occurs in an unconfined shallow alluvial zone. Monitoring wells have been installed to monitor groundwater elevation and to collect analytical groundwater samples. Monitoring well locations are illustrated in **Figure 1-2**. Monitoring of the groundwater has taken place in August 2011, November 2011, January 2012, and May 2012. During August 2011, the water table depth ranged from 4.01 feet to 9.70 feet bgs. During November 2011, the depth to groundwater ranged from 7.25 feet to 12.46 feet bgs. During the January 2012 monitoring event, depth to groundwater ranged from 9.46 feet to 14.75 feet bgs. During the May 2012 monitoring event, depth to groundwater ranged from 5.24 feet to 13.61 feet bgs. Groundwater elevation data is provided in **Table 3-1**. A hydrograph displaying the seasonal groundwater fluctuation over time is provided as **Figure 3-4**.

During the August 2011 and May 2012 groundwater monitoring, the direction of shallow groundwater flow was east to northeast. During the November 2011 and January 2012 groundwater monitoring, the direction of shallow groundwater flow was generally in an east to southeast direction. The groundwater flow direction is likely influenced by irrigation on the adjacent cropland. Groundwater elevation maps showing flow directions are illustrated in **Figures 3-5** through **3-8** for August 2011, November 2011, January 2012, and May 2012, respectively. No light non-aqueous phase liquid (LNAPL) was observed in any of the monitoring wells during the 2011 and 2012 monitoring events. The calculated hydraulic gradient ranged from 0.0064 feet per foot (ft/ft) in August 2011 to 0.013 ft/ft in May 2012.

In 2009 a slug test was performed at the Site using Monitoring Well MW-2. The results of the slug test yielded a hydraulic conductivity (K) value of 0.0026 feet per day (Trihydro Corporation 2009). This value is on the low end of the hydraulic conductivity range of unconsolidated silt (Trihydro Corporation 2009). The Site-specific porosity was calculated at 0.39, 0.43, and 0.44 from three separate intervals of SB-5-11 during the 2011 investigation (**Appendix B**). Based on an average porosity of 0.42 and the 2011 and 2012 calculated hydraulic gradients, the average linear groundwater velocity at the Site ranges from  $4.0 \times 10^{-5}$  feet per day (0.01 feet per year) to  $8.0 \times 10^{-5}$  feet per day (0.03 feet per year).

### 3.3 Site Surface Water

Surface water near the Site consists of irrigation ditches, irrigation canals, and a section of Five Mile

Creek. The south and east portions of the Site are bordered by an irrigation ditch and 12-inch-diameter polyvinyl chloride irrigation pipe. A second irrigation ditch (unlined) is located approximately 0.10 mile to the south of the Site. This ditch flows from west to east bordering Harris Bridge Road. Five Mile Creek is located approximately 0.25 mile to the northeast of the Site. Five Mile Creek flows from west to east in a down valley direction. Surface water runoff at the Site likely flows from the Site radially towards adjacent fields as the Site is a topographic high in the immediate area. Groundwater levels and flow direction at the Site are likely to be influenced by irrigation in adjacent fields. The nearby irrigation water does not flow over the Site.

### **3.4 Nature and Distribution of Site Impacts**

#### **3.4.1 Sources**

Current groundwater conditions show evidence of impact from petroleum hydrocarbon releases. From Site investigations it has been determined that the source for the groundwater petroleum hydrocarbon impacts at the TP 42x-11 Site is a former unlined production pit that was used until 1995 to hold produced water during the gas well drilling and production processes. The unlined production pit was excavated in 2008. Soil appears to have been removed to petroleum hydrocarbon concentrations below WDEQ soil clean-up levels. This is based on the results of the confirmation soil sampling immediately following the excavation activities (KC Harvey 2010) and the subsequent 2011 soil assessment presented in Section 2.1. The remaining impacts are present in the dissolved phase or adsorbed onto saturated zone subsurface soil.

#### **3.4.2 Migration Pathways**

A dissolved phase hydrocarbon plume has migrated downgradient of the pit in the subsurface through groundwater. Dissolved phase contaminants in the groundwater migrate downgradient in various directions predominately northeasterly to easterly, to southeasterly following the hydraulic flow direction at different times of the year. As water levels across the Site fluctuate due to precipitation and irrigation events, soil in contact with the rising and falling groundwater may become impacted. Smear zone impacts were observed in subsurface soil in 2011 during Site investigations surrounding the previously excavated unlined pit. During the 2011 investigation, petroleum hydrocarbon impacts were not observed in soil above the water table. Boring logs detailing observations of petroleum hydrocarbon impacts surrounding the production pit are provided in **Appendix A**.

#### **3.4.3 Soil Conditions**

Soil investigation activities were conducted at the Site in 2006, 2007, and 2011. Excavation of petroleum impacted soil was performed in 2008 with the subsequent collection of excavation confirmation samples. The excavation was effective in removing vadose zone impacted soil based on the results of the excavation confirmation sampling (KC Harvey 2010) and the 2011 supplemental Site characterization activities (Section 2.1). All petroleum hydrocarbon impacted soil above the water table has been removed and no further soil remediation is required at the Site. All remaining soil impacts were observed at levels below the high water table fluctuation level (i.e., smear zone). These observations are based on visual staining, elevated PID measurements, and elevated concentrations of compounds of interest (COI) during the 2011 soil investigation.

During the 2011 soil investigation, select soil samples were collected from Soil Boring SB-5-11 at depths below the groundwater table. These soil samples were collected to support development of a saturated zone remedial approach. In the two soil samples collected from Soil Boring SB-5-11 at intervals of 16 to 18 feet bgs and 18 to 20 feet bgs, ethylbenzene, total xylenes, and naphthalene were detected at concentrations above the migration to groundwater clean-up levels. This is consistent with the historical groundwater sampling results.

#### **3.4.4 Groundwater Conditions**

The Site currently has six permanent monitoring wells and one temporary well (WT-1-11) installed on-site and on adjacent properties to monitor groundwater petroleum hydrocarbon concentrations. The Site plan (**Figure 1-3**) illustrates the locations of all monitoring wells. In 2011 and 2012, multiple groundwater monitoring events were conducted to determine current and seasonal groundwater conditions. Groundwater monitoring events were conducted in August 2011, November 2011, January 2012, and May 2012. Five monitoring wells were sampled during the August 2011 sampling event. Seven monitoring wells were sampled during the November 2011, January 2012, and May 2012 events. Samples were collected to monitor dissolved phase petroleum hydrocarbon impacts in the groundwater. No LNAPL has been observed at the Site. Samples collected during the 2011 and 2012 monitoring events were analyzed for TPH-GRO, TPH-DRO, volatile organic compounds (VOCs), and geochemical parameters for monitoring natural attenuation (MNA) including nitrate, sulfate, and ferrous iron. An evaluation of MNA is provided in Section 3.6.

During the 2011 and 2012 sampling events, benzene, TPH-GRO, and TPH-DRO were detected in Site monitoring wells above the applicable Maximum Contaminant Levels (MCLs). All detections above MCLs are limited to monitoring wells located on the well pad. A map depicting the extent of benzene concentrations in groundwater is provided as **Figure 3-9**. Analytical results are summarized in **Table 2-2**.

Semi-volatile organic compounds (SVOCs) were not sampled for during the 2011 and 2012 groundwater sampling events. Naphthalene and 2-methylnaphthalene were analyzed in 2008 and 2009 and the results are included in **Table 2-2**. Both compounds have been detected at the Site with one detection of 2-methylnaphthalene (MW-4 dated March 2009) above the clean-up level. All other detections of naphthalene and 2-methylnaphthalene are below the applicable clean-up levels. The presence of these compounds guides which clean-up level to use for TPH-DRO (as shown in **Table 2-2**).

### 3.5 Potential Receptors

The petroleum hydrocarbon impacts at the Site are confined to groundwater beneath the well pad as described in Section 3.4.4. This is evident by the lack of petroleum hydrocarbon detections in groundwater in downgradient Monitoring Wells MW-1, MW-5, and MW-6 and the minimal detections of TPH-DRO only in Monitoring Well MW-4.

Although the groundwater impacts are confined to groundwater beneath the well pad based on information gathered to date, the potential for off-site transport of petroleum hydrocarbon impact in the vicinity of the Site was evaluated. This section discusses potential human and ecological receptors in the immediate vicinity of the Site, including workers, residents, sensitive populations, surface water features, and wells within a specified radius of the Site. The potential receptors identified in the following sections are shown in **Figure 3-10**.

#### 3.5.1 Human Receptors

Potential human receptors affected by petroleum hydrocarbon impact migration include Site workers, adjacent property workers, and nearby residents. Site workers may be affected by petroleum hydrocarbon impacts depending on the type of work being performed and the duration. Because petroleum hydrocarbon impacts exist only in the subsurface, it is not likely that Site workers performing periodic activities will be affected unless excavation into the subsurface occurs. Adjacent property workers may include agricultural workers in adjacent fields. Agricultural workers are not likely to be affected by subsurface petroleum hydrocarbon impacts because, as discussed below, groundwater impacts are confined within the vicinity of the well pad.

The nearest two residences are located approximately 2,100 feet north and 2,500 feet northeast of the Site. The nearest residence to the east is located approximately 3,000 feet from the Site. The residences should not be affected by subsurface petroleum hydrocarbon impacts because

groundwater impacts are confined within the vicinity of the well pad as described in Sections 3.4.4 and 3.5. There are no other potential sensitive populations located in the vicinity of this Site.

### 3.5.2 Surface Water and Domestic Well Receptors

Surface water features and domestic wells act as possible receptors for off-site petroleum hydrocarbon impact migration. The nearby surface water features include irrigation ditches and canals which empty into Five Mile Creek located approximately 0.25 mile to the northeast of the Site. The nearest surface water feature is an irrigation ditch approximately 0.10 mile south of the Site. The irrigation ditches and Five Mile Creek should not be affected by subsurface petroleum hydrocarbon impacts because groundwater impacts are confined within the vicinity of the well pad. This is confirmed by the lack of petroleum hydrocarbon detections in groundwater in Monitoring Well MW-5 located between the Site and Five Mile Creek.

Domestic and stock wells act as potential receptors to off-site petroleum hydrocarbon impact migration. The closest domestic well (PGDW24) to the Site is located at a residence approximately 2,100 feet to the north of the Site. This well is generally cross-gradient of the Site and is not likely to be influenced by off-site petroleum hydrocarbon migration. The next closest domestic wells are PGDW20/21 (approximately 3,000 feet east/downgradient), PGDW26 (approximately 3,000 feet west/upgradient), and PGDW36 (approximately 2,500 feet northeast/cross-gradient). Wells PGDW26 and PGDW36 are not likely to be influenced by off-site petroleum hydrocarbon migration because they are located up and cross-gradient of the Site. Wells PGDW20 and PGDW21 are located generally downgradient but are not likely to be affected by off-site hydrocarbon migration because groundwater impacts are confined within the vicinity of the well pad as described in Sections 3.4.4 and 3.5. There are no stock wells located within a 1-mile radius of the Site.

### 3.6 Natural Attenuation Evaluation

An evaluation of natural attenuation was conducted based on the historical groundwater monitoring data and the 2011 and 2012 geochemical data collected at the Site. The purpose of the evaluation is to identify the potential for remaining COI concentrations to achieve regulatory standards through natural processes (natural attenuation) based on current Site conditions. This evaluation was conducted in accordance with WDEQ VRP Fact Sheet #26 (WDEQ 2007a).

In accordance with Fact Sheet #26, "primary" and "secondary" "lines of evidence" were used to assess the natural attenuation of Site COIs.

- Primary lines of evidence are historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing contaminants and /or concentration over time at appropriate monitoring or sampling points.
- Secondary lines of evidence are hydrogeologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the Site, and the rate at which such processes will reduce contaminant concentrations to required levels.

#### 3.6.1 Primary Lines of Evidence

The primary lines of evidence were evaluated to determine if the areas of affected groundwater are stable or shrinking. Historical groundwater monitoring results are included in **Table 2-2**. Two methods were used to evaluate the primary lines of evidence: 1) Mann-Kendall Trend Test (MKTT); and 2) linear regression analysis.

##### 3.6.1.1 Mann-Kendall Trend Test

The WDEQ VRP Fact Sheet #26 suggests the use of statistical methods and approaches as provided in Wisconsin Department of Natural Resources (WDNR) Guidance on Natural Attenuation for Petroleum Releases for use in meeting the primary lines of evidence evaluation (WDNR 2003). The

WDNR guidance provides discussion of the MKTT statistical method. The MKTT is a statistical method that is used to assess if groundwater constituent concentrations are increasing in value, are stable, or are decreasing. The test involves computing a statistical value, S, and determining if S is a positive value (increasing data trend), negative value (decreasing data trend), or no data trend. If S is negative or indicates no trend, then the plume in the affected groundwater area is considered shrinking or stable. The MKTT requires a minimum of four rounds of sampling results. Approximately 4 to 5 years of data were used for the MKTT trend test evaluation on MW-2 and MW-4. Only 1 year (four quarters) of data was used for WT-1. The MKTT results are included in **Appendix C**.

Benzene, TPH-DRO, and TPH-GRO are the only COIs at the Site that routinely exceed the applicable cleanup levels. 2-methylnaphthalene was only analyzed for in one sampling round in March 2009 and exceeded the MCL at MW-4. Since only one data point was available, 2-methylnaphthalene is not included in this evaluation. Trends were evaluated for benzene, TPH-DRO, and TPH-GRO concentrations at Wells MW-4 and WT-1-11. Trends were evaluated for benzene and TPH-DRO concentrations at Monitoring Well MW-2. The MKTT results were compared to the linear regression analysis as described below in Section 3.7.2 and shown on the trend graphs provided in **Appendix C**.

The MKTT for benzene exhibits decreasing trends at both MW-2 and MW-4 and an increasing trend at WT-1. Of note, only 1 year, or four quarters, of data were used for the WT-1 evaluation.

The MKTT for TPH-DRO does not exhibit concentration trends for any of the wells analyzed.

The MKTT for TPH-GRO exhibits a decreasing trend for MW-4 and no concentration trend was identified for WT-1.

#### **3.6.1.2 Linear Regression Analysis**

Semi-log graphs of COI concentrations over time were prepared for the same wells used for the MKTT evaluation above. Trend graphs are provided in **Appendix C**. A downward sloping trend line (first-order decay constant less than zero) indicates decreasing constituent concentrations or a shrinking area of affected groundwater. An upward sloping trend line indicates increasing constituent concentrations or an expanding area of impact. A "no trend" determination was given for wells showing a low to negligible coefficient of determination, or r-squared value.

Linear regression analysis confirms trends identified by MKTT with one exception. TPH-GRO trend using linear regression exhibits a decreasing concentration trend, whereas, no trend was identified based on the MKTT result.

#### **3.6.2 Secondary Lines of Evidence**

Secondary lines of evidence use chemical and physical data to determine whether contaminant mass is being reduced. Biodegradation is the primary natural attenuation mechanism for reducing COI mass and concentration. The effectiveness of biodegradation can be evaluated by measuring geochemical indicators and metabolic byproducts in groundwater.

Field measurements have been collected for dissolved oxygen (DO) and oxidation reduction potential (ORP) in all of the groundwater monitoring wells during four sampling events conducted since August 2011. Groundwater samples also have been laboratory analyzed for sulfate, nitrate, and ferrous iron in each of the four sampling events. A copy of the sampling field forms is provided in **Appendix A**.

Benzene is most easily degraded when sufficient oxygen is present or under aerobic conditions, but may degrade at a slower rate when oxygen is depleted. In an environment conducive to natural attenuation, decreasing concentrations of DO, nitrate, and/or sulfate should be present within the area of dissolved benzene. Conversely, increasing values of iron (II) should be present within the area of dissolved benzene.



The groundwater flows across the Site as described in Section 3.2. Based on the general direction of groundwater flow, Wells MW-1, MW-4, MW-5, and MW-6 are seasonally downgradient or cross-gradient of the former production pit (i.e. source), and Well MW-3 is generally upgradient of the source. Wells MW-2 and WT-1-11 are located within the benzene plume.

The sequential use of electron acceptors as microorganisms consume contaminants is:

DO → Nitrate → Manganese (IV) → Iron (III) → Sulfate → Carbon Dioxide

- **DO and ORP.** The DO concentrations at the Site are generally low within the plume area, and show moderate variation, ranging between 0.64 milligrams per liter (mg/L) and 1.58 mg/L. The DO concentrations in the upgradient well ranged from 1.87 mg/L to 5.8 mg/L during the 2011 and 2012 sampling events. The ORP measurements are generally lowest at plume Wells MW-2 and WT-1-11. The lowest ORP measurements were recorded at WT-1-11, located within the former pit area, ranging between -325.4 millivolts (mV) and -348 mV during three sampling events since August 2011. Positive ORP values were recorded during two or more sampling events at wells MW-3, MW-5, and MW-6. The DO and ORP concentrations measured across the Site generally support the occurrence of anaerobic degradation.
- **Nitrate.** A reduction in nitrate concentrations following oxygen reduction is typically observed within the dissolved plume when biodegradation is occurring. In wells located outside of the benzene plume, nitrate ranged between 0.84 mg/L and 8.9 mg/L and was detected in each well during each of the four sampling events since August 2011. In Wells MW-2, MW-4 and WT-1-11, located in or near the plume, the nitrate concentration ranged from below detection to 1.4 mg/L. Nitrate was detected only once in each plume well since August 2011. This data supports the occurrence of anaerobic degradation at the Site.
- **Iron (III).** The use of iron (III) as an electron acceptor in anaerobic groundwater plumes is evaluated through measurement of the metabolic byproduct iron (II). An indication of the occurrence of biodegradation is evidenced by increasing concentrations of iron (II), yielding the reduction of iron (III) within the dissolved plume. Concentrations of iron (II) are greatest in Wells MW-2, MW-4 and WT-1-11, with concentrations ranging from 0.79 mg/L to 8.8 mg/L. Iron (II) was detected in each of these wells during every sampling event since August 2011. The iron (II) concentration in the remaining wells, all located outside of the benzene plume, were either non-detect or less than 0.33 mg/L during all sampling events since August 2011. This iron (II) data supports the occurrence of anaerobic degradation at the Site.
- **Sulfate.** Under ideal reducing conditions following the depletion of oxygen, nitrate, manganese, and ferric iron, sulfate can be used as an electron acceptor within the dissolved plume. Sulfate values supporting anaerobic biodegradation should decrease in areas of groundwater contamination. Sulfate concentrations across the Site are generally elevated. The lowest sulfate concentrations were measured in Well MW-4, ranging from 12 mg/L to 85 mg/L during four sampling events since August 2011. While MW-4 sulfate data is lower than peripheral Wells MW-3 and MW-5, the contribution of sulfate as an electron acceptor is not clear.

Concentrations of DO, ORP, sulfate, nitrate, and iron (II) from each of the four sampling events from August 2011 through May 2012 are summarized in **Figure 3-11**.

### 3.6.3 Natural Attenuation Evaluation Conclusions

The MKTT and linear regression analysis for Wells MW-2 and MW-4 indicate decreasing benzene and TPH-GRO concentration trends in the plume area downgradient from the former production pit. Based on the MKTT evaluation of the four quarters of available data collected at Temporary Monitoring Well WT-1-11, the benzene trend is increasing in the immediate source area within the former production pit. The increasing benzene trend at source area Well WT-1-11 is an indicator that this area may

require engineering technologies to enhance biodegradation rates in the source area. The DO, ORP, nitrate, and Iron (II) data collected from Site wells indicate the presence of geochemical processes favorable to natural attenuation.

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## 4.0 Criteria for Remedial Alternative Evaluation

This section describes the performance objectives and selection criteria used to evaluate and select an appropriate remedial alternative for this Site.

### 4.1 Performance Objectives

Successful completion of remedial activities will be based on the achievement of clean-up levels as defined by the WDEQ VRP Fact Sheet #12 (Soil Clean-up Levels), VRP Fact Sheet #13 (Groundwater Clean-up Levels), and summarized in the WDEQ Solid and Hazardous Waste Division (SHWD) clean-up level spreadsheet effective June 30, 2009. As described in Section 2.1 and Section 3.4.3, soil clean-up objectives have been met and further soil remedial activities are not warranted. The site-specific COIs that exceed groundwater MCLs are benzene, TPH-DRO, TPH-GRO, and 2-methylnaphthalene (March 2009). The clean-up levels for these Site-specific COIs are summarized in **Table 4-1**.

### 4.2 Basis for Analysis

The remediation alternatives were evaluated based on three general or primary standards: 1) protection of human health and the environment; 2) ability to attain media clean-up standards; and 3) compliance with applicable standards for management of wastes. Additionally, they were evaluated using a set of secondary selection factors: reliability and effectiveness, ability to reduce toxicity or volume of constituents, treatment timeframe, implementability, cost, and sustainability. Below is a description of each criterion:

#### General Standards

- Be Protective of Human Health and the Environment. This criterion addresses the alternative's overall ability to provide adequate protection of human health and the environment through eliminating, reducing, or controlling potential exposure.
- Attain WDEQ/USEPA Clean-up Standards. Each alternative is evaluated based on its ability to achieve the clean-up objectives.
- Comply with Any Applicable Standards for Management of Wastes. This criterion requires that wastes generated during the implementation of the alternative will be managed in compliance with applicable regulations.

#### Remedy Selection Decision Factors

- Reliability and Effectiveness. This criterion addresses whether the alternative is reliable and effective in protecting human health and the environment during the life of the alternative. The life of the alternative is the length of time the alternative must be operated and maintained and/or a monitoring program implemented. Timeframes used in this RAE are based on the time to reach clean-up goals determined by calculated degradation rates or estimated alternative implementation duration.
- Reduction in Toxicity and/or Volume of Wastes. This criterion considers how each alternative reduces the toxicity and/or volume of wastes.
- Treatment Timeframe. This criterion considers the timeframe required to reach media clean-up goals for the alternative.
- Implementability. The constructability of each alternative was considered, as well as the ability to monitor the effectiveness of the alternative.

- **Cost.** The relative cost of each alternative was considered. Costs include capital construction; engineering design, construction oversight, and project management; and periodic costs. As described above, the timeframe of each alternative is based on the time to reach media clean-up goals determined by calculated degradation rates or estimated alternative implementation duration.
- **Sustainability.** Green and Sustainable Remediation (GSR) takes into consideration the environmental impacts of Site clean-ups and implements measures to mitigate these environmental impacts and increase the overall sustainability of Site remedies (WDEQ 2012a).

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## 5.0 Development and Evaluation of Alternatives

This section presents the development of alternatives and a detailed description of each alternative.

### 5.1 Alternative Development

Section 5.2 provides descriptions of the individual treatment technologies that are included in this remedial alternatives evaluation. These technologies have been combined to form the remedial alternatives described in Section 5.3. The alternatives were developed based on the results of previous investigations at the Site, remediation results at similar sites, screening of available technologies, and performance objectives. Each remedial alternative has been evaluated based on the criterion described in Section 4.0, and the evaluation results are presented in Section 5.3.

### 5.2 Remediation Technology Descriptions

Potentially applicable remedial technologies for the treatment of petroleum hydrocarbon containing groundwater are described in this section. The advantages, disadvantages, limitations, regulatory and economic concerns, and feasibility for each technology are discussed. Potentially applicable technologies to remove hydrocarbons and/or contain hydrocarbon migration include:

- MNA;
- Excavation and treatment;
- In situ bioremediation; and
- In situ air sparging with soil vapor extraction.

#### 5.2.1 Monitored Natural Attenuation

MNA relies on natural attenuation processes (within the context of a carefully controlled and monitored Site clean-up approach) to achieve site-specific remedial objectives (USEPA 1999). Natural attenuation utilizes naturally occurring physical, chemical, and/or biological processes to degrade contaminants and limit their movement in the subsurface. Typically petroleum hydrocarbons degrade to less harmful products. The effectiveness of MNA of petroleum hydrocarbons is dependent on the mass of contaminant in the environment, the availability of electron acceptors, and the ability of the existing microbial population to degrade the contaminants. The limiting factor of the biodegradation rate for the large majority of BTEX plumes is oxygen supply.

**Advantages:** Natural attenuation processes occur to some extent in all petroleum hydrocarbon contamination sites. The natural attenuation of groundwater, coupled with an active source clean-up, can be very effective for petroleum hydrocarbon releases. Because this alternative is relatively non-intrusive, it can be used in conjunction with, or as a follow-up to, other remedial alternatives. Relatively little remediation waste is generated using this alternative and minimal short-term risk of human exposure is experienced through MNA. This alternative is generally the least expensive remedial technology, even when considering the long-term costs associated with implementing the monitoring program.

**Disadvantages:** The time frame to achieve remedial action goals using MNA is typically very long compared to other remedial alternatives. The residual impacts in saturated soil could act as a continuing source of hydrocarbons and increase the remediation time frame. As such, source control actions may be necessary in conjunction with natural attenuation.

**Site Specific Evaluation:** MNA sampling was conducted during the 2011 and 2012 quarterly

groundwater monitoring events. The findings indicated that the benzene plume is stable to shrinking and the occurrence of biodegradation appears to be present at the Site as presented in Section 3.6. Given the relatively low levels of dissolved-phase hydrocarbons and the lack of continuing source material in the soil or as LNAPL, MNA could be a potential stand-alone technology for the Site. Due to increasing benzene trends in the immediate source area (WT-1), the clean-up time-frame using MNA could be decreased with additional dissolved phase source area treatments.

### 5.2.2 Smear Zone Excavation

Smear zone excavation as a groundwater remediation technology involves the physical removal of the affected saturated soil containing high dissolved-phase COI concentrations. Based on the results of prior investigations, the affected soil at the Site exists within the smear/saturated zone below the vadose zone. The excavated saturated soil is transported off-site for treatment or disposal. Excavation of affected saturated soil, specifically hydrocarbon-containing soil, completely removes the soil source area, thereby facilitating groundwater remediation. Excavation technology is executed using common construction methods such as backhoes and track excavators. During excavation, groundwater dewatering may be required and the groundwater removed from the excavation must be contained, characterized, and properly disposed. When excavation is selected, factors such as safety, soil properties and stability, extent of contamination, depth of contamination, depth to groundwater, volume of soil, site development including structures and subsurface utilities, water management, landfill disposal parameters, and transport distances should be considered.

**Advantages:** Excavation generally results in significant reduction in remediation time and is typically very effective, widely accepted by federal and state agencies, equipment is readily available, and it can be applied to a wide variety of contaminants. This is possible because excavation involves the removal of the soil matrix and does not depend on permeability to move hydrocarbons out of the soil. Excavation is most feasible when small quantities of affected soil are involved, the Site is undeveloped, the natural soil permeability is low, and/or the depth of soil to be remediated is shallow and accessible to excavation equipment.

**Disadvantages:** Excavation is typically not cost-competitive with other technologies for large volumes of soil. At the Site, a significant volume of clean overburden would require removal prior to removal of the smear zone or saturated soil. Groundwater dewatering would be required for the smear zone excavation occurring below the groundwater table. The treatment of impacted soil at a land treatment facility requires a large area and ongoing maintenance in order to achieve permitted levels for beneficial reuse of the soil.

**Site Specific Evaluation:** Excavation would be conducted in the source area in the vicinity of the former production pit. Excavation at this Site would require initial removal of clean overburden soil in the vadose zone to depths of approximately 10 feet. The impacted saturated zone would be excavated from approximately 10 to 15 feet bgs based on field observations during the soil boring advancement at temporary Monitoring Well WT-1-11. The work would require saturated zone dewatering because the excavation would extend below the water table. The water generated during dewatering would be transported to the Riverton Wastewater Treatment Facility. The soil generated would be transported to Encana's WDEQ permitted land treatment facility located nearby in the Pavillion field.

### 5.2.3 In situ Bioremediation

In situ, bioremediation or enhanced aerobic biodegradation, involves the addition of oxygen (an electron acceptor) to groundwater to increase the population of native petroleum hydrocarbon degrading microorganisms. The increased biodegradation reduces concentrations of impacts in the groundwater at a greater rate. This can be accomplished by in situ injection of air, oxygen, or oxygen release amendments as liquid or solid or placement of oxygen release amendments in an excavation. The supplemental source of oxygen is made available to the native bacteria for biodegradation as described in Section 5.2.1. This technology as evaluated for this Site refers to the subsurface injection

or post-excavation placement of an oxygen release remediation amendment such as Oxygen Release Compound® (ORC) or equivalent. The oxygen amendment could be injected into a series of injection points or wells within the impacted zone or placed within the saturated zone immediately following excavation as described in Section 5.2.2. The amendment slowly releases oxygen into the saturated zone over a period of up to 12 months for enhanced aerobic biodegradation. Injection of the oxygen amendment is accomplished using direct push injection technologies to distribute the oxygen amendment into the saturated zone at pressure within various vertical discrete intervals ranging from 2 to 5 feet thick. The post-excavation placement of the oxygen amendment is accomplished by mixing the amendment into the saturated zone soils using conventional construction equipment.

**Advantages:** The advantages of biodegradation described in Section 5.2.1 also apply to in situ bioremediation. The amendments used for oxygen enhancement are environmentally safe. Since the treatment occurs in situ, only minimal waste is generated. Only minimal site disturbance is required through injections with no long-term infrastructure changes. Long-term operation and maintenance is not required with bioremediation injections.

**Disadvantages:** This technology requires successful subsurface distribution. It is difficult to achieve the necessary injection distribution in the tight and low permeable formations that exist at the Site. Lower hydraulic conductivities may inhibit the migration of oxygen enhanced groundwater.

**Site Specific Evaluation:** An ORC injection pilot test was conducted at a nearby site in the Pavillion field (AECOM 2012). The data is currently being evaluated and the pilot test report has not been completed. A preliminary review of the results indicates that the injection radius of influence was at least 10 feet and the ORC appears to have positive influence on a target monitoring point located 20 feet from injection activities. Injection of an oxygen amendment at the Site would involve direct push injections in the source and plume area. At this Site, the dissolved phase concentrations can reasonably be treated with an application of oxygen amendment to enhance biodegradation. If successful distribution is achieved, it is anticipated that significant degradation would occur in the first 3 months. The data from injection activities at this Site would be used to support the design for follow-up injections, if necessary, or other similar sites if applicable.

#### **5.2.4 Air Sparge and Soil Vapor Extraction**

Air sparging (AS) involves the injection of air into the saturated zone within areas of dissolved phase impacts. During sparging, the dissolved-phase and soil adsorbed compounds are stripped into the vapor phase. The stripped vapors are then recovered from the vadose zone during the simultaneous operation of soil vapor extraction (SVE). Air sparging also adds oxygen to the groundwater for additional enhancement of aerobic biodegradation.

**Advantages:** Air sparging actively remediates groundwater in situ without removing groundwater. Air sparging is a common technology with proven success at similar sites.

**Disadvantages:** This technology relies on moving air through saturated porous medium. Vertical air channeling may occur in the subsurface. This technology requires simultaneous operation of an SVE component. Sustained energy is required for operation of the mechanical components of the AS/SVE system. Frequent visits to the Site are necessary for operation, monitoring, and maintenance (OM&M) of the remediation system.

**Site Specific Evaluation:** AS/SVE would involve a remediation well network within the source and plume area. The AS radius of influence would be evaluated during an AS pilot test. The pilot test results would be used for full scale design. The AS injection wells would be installed with approximately 2 feet of screened interval at approximately 5 to 7 feet bgs. The SVE wells would be installed with approximately 5 feet of screen interval within the vadose zone for vapor capture. Geotechnical data collected in August 2011 indicates the intrinsic permeability of the soil may work for AS/SVE, but its effectiveness may be limited because the clay layers impede air flow and may limit air

distribution.

### **5.3 Detailed Description and Evaluation of Alternatives**

A detailed description of each alternative and the summary of the alternative evaluation is provided below. A summary of each alternative compared to the evaluation criteria with the final comparative ranking is provided in **Table 5-1**. All of the alternatives evaluated were considered to satisfy the general standards for remedies (protection of human health and the environment, ability to attain media clean-up standards, and compliance with applicable standards for management of wastes).

#### **5.3.1 Alternative 1 – MNA for Site Treatment**

This alternative includes implementation of long-term MNA only.

This alternative was given an overall ranking of second among the four alternatives. This alternative ranked high for implementability, cost, and sustainability. This alternative ranked high among these criterions because a MNA program can be implemented during routine groundwater sampling. Lower rankings were given to this alternative for reduction in toxicity, mobility, or volume of wastes, and short-term effectiveness. The low ranking was applied because this alternative would take the longest time to achieve Site clean-up due to reliance solely on natural processes.

#### **5.3.2 Alternative 2 – Smear Zone Excavation of Source Area, Oxygen Release Product in Base of Excavation for Plume Treatment with MNA**

This alternative includes removing the smear zone impacted saturated soil through excavation, placement of an oxygen release product in the base of the excavation for enhanced biodegradation, and MNA.

This alternative was given an overall ranking of third (tied with Alternative 4) among the four alternatives. This alternative ranked high for long-term reliability and effectiveness and short-term effectiveness. This alternative ranked high among these criterion because once the impacted medium is physically removed and an oxygen release product is placed directly in the impacted groundwater, the alternative is instantly effective. This alternative ranked low for implementability, cost, and sustainability because the remedy requires removal of a large volume of clean overburden prior to accessing the impacted subsurface zones; continuous operation of heavy equipment and soil transport during implementation; and long-term maintenance when placed in the land treatment facility for long-term soil treatment.

#### **5.3.3 Alternative 3 – In Situ Bioremediation for Source Area and Plume Treatment with MNA**

This alternative includes injection of an oxygen release product into the saturated zone within the source and plume area and MNA.

This alternative was given an overall ranking of first among the four alternatives. This alternative ranked high for long-term reliability and effectiveness, reduction in toxicity and/or volume of wastes, and sustainability. This alternative ranked high among the effectiveness and reduction criterion because it is a proven technology for the remediation of petroleum hydrocarbons. This is a sustainable alternative because it requires only one mobilization to the Site for injections and subsequently uses natural biological processes for degradation of impacts. This alternative did not rank low for any of the criteria. Although this technology is proven and common in the industry, it received a moderate ranking for implementability due to the unknown factor of injectability at the Site.

#### **5.3.4 Alternative 4 – AS and SVE for Source Area and Plume Treatment with MNA**

This alternative includes air sparging in the saturated zone with SVE in the vadose zone and MNA.



This alternative was given an overall ranking of third (tied with Alternative 2) among the four alternatives. This alternative ranked high for long-term reliability and effectiveness and reduction in toxicity and/or volume of wastes. This alternative ranked high among the effectiveness and reduction criterion because it is a proven technology for the remediation of petroleum hydrocarbons. This alternative ranked low for implementability, cost, and sustainability. The low implementability ranking was because it undefined how power would be achieved for the AS/SVE system operation and how well air distribution in the subsurface would be achieved. It ranked low for cost and sustainability due to the capital costs for system installation, power requirements, and frequent OM&M visits.

#### **5.4 Selected Alternative**

The alternative selected based on this evaluation is the one-time injection of an oxygen release product for source area and plume treatment followed by MNA. This technology is expected to result in short-term reduction of source area concentrations and contribute to long-term reduction of impacts through natural processes. The work plan for this remedy is presented in Section 6.0.

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## 6.0 Selected Remediation Work Plan

This section presents the conceptual design and scope of work for remedy implementation at the Site. Components described below include groundwater monitoring, well abandonment, remediation injection, groundwater monitoring, investigation derived waste (IDW) management, data evaluation, and reporting. Data collection activities will be conducted according to the procedures set forth in this work plan and accompanying AECOM Project Operating Procedures (POPs) (**Appendix D**).

### 6.1 Safety, Health, and Environment

All Site work will be conducted in accordance with the site-specific Health and Safety Plan (HASP), which will be developed prior to mobilization to the Site. The HASP will be available for on-site inspection. All on-site personnel will be required to follow the procedures outlined in the HASP. The HASP will include contingency measures in the event of unanticipated situations during fieldwork operations. In addition, a safety "tailgate" meeting will be initiated at the inception of field work each day and after lunch or breaks at the discretion of the field manager.

### 6.2 Ground Disturbance Requirements

At least 2 days prior to field activities, One Call of Wyoming will be contacted for utility notification. In accordance with Encana's Ground Disturbance Practice, all utilities within a 100-foot radius search area will be marked and all utilities within 15 feet of proposed injection locations will be positively identified using air or water excavation.

### 6.3 In Situ Bioremediation

In situ bioremediation will be implemented through direct push injections of an oxygen release product such as ORC-Advanced (ORC-A) or PermeOx® Plus. The oxygen release product and application information is provided in **Appendix E**.

The bioremediation injections will be implemented within the existing groundwater source and plume in the vicinity of Monitoring Wells WT-1-11, MW-2, and MW-4, as shown in **Figure 6-1**. All injections will be performed using direct push injection technology. The oxygen release product will be mixed into a slurry at the surface and pumped into the injection rods through high pressure lines. The injection tool may be up to 5 feet in length. The injection tool will consist of a steel rod that contains perforated, radial injection ports or a similar injection tool design as approved by the project engineer. All injection points will be temporary. Up to 22 points will be injected as shown in **Figure 6-1**. The injection area will extend to the east of Monitoring Wells MW-2 and MW-4 to encompass SB-5-11 in order to address the impacts noted from the August 2011 investigation. Injections will be from approximately 5 to 20 feet bgs to cover the entire smear zone. The injections will be completed to a total depth of 20 feet bgs to ensure the treatment area encompasses the current known vertical zone of impacts. Each point will be injected with approximately 135 to 180 pounds of oxygen release product and approximately 50 gallons of water for a total of up to 3,600 pounds of oxygen release product and 1,100 gallons of water.

The injection well layout is designed for both source area and plume treatment. The oxygen release product will disperse in the downgradient direction with the groundwater flow. As described in Section 3.2, the hydraulic conductivity and calculated average flow velocity at the Site is very low. The injection well layout is planned using a grid pattern that assumes a radius of influence of approximately 6 feet to accommodate the minimal groundwater flow characteristics at the Site. Only one injection event is planned to enhance biodegradation at the Site.

#### 6.4 Permits and Regulatory Requirements

A Class V Underground Injection Control (UIC) permit will be obtained from the WDEQ Water Quality Division (WQD) prior to the injections and submitted to the WDEQ/VRP prior to field activities. The UIC permit application form is provided in **Appendix F**.

#### 6.5 Groundwater Monitoring Plan

Monitoring of the bioremediation injections will be performed monthly over the course of 6 months for a total of six monitoring events to evaluate the reduction rate of the BTEX and TPH in the dissolved phase plume at WT-1-11, MW-2, and MW-4. Groundwater monitoring and sampling will be performed on all Site monitoring wells on a quarterly basis for the first year following injections and semi-annually thereafter to monitor remediation effectiveness and for natural attenuation. Groundwater monitoring and sampling will continue until clean-up levels have been achieved, as well as one additional year to confirm concentrations remain below the applicable clean-up levels.

Groundwater samples will be submitted for laboratory analysis of BTEX, TPH-GRO, and TPH-DRO during each sampling event. Two groundwater samples, one from MW-2 and one from MW-4, will be laboratory analyzed annually for SVOCs to determine current concentrations of naphthalene and 2-methylnaphthalene for determination of the TPH-DRO clean-up level per Fact Sheet #13. If naphthalene and 2-methylnaphthalene are not detected at the Site, the TPH-DRO clean-up level will increase to 10 mg/L from the current clean-up level of 1.1 mg/L (**Table 4-1**). Groundwater samples will be analyzed at least once per year for the geochemical parameters sulfate, nitrate, and ferrous iron for MNA. The collection of water level measurements and groundwater samples using low-flow sampling techniques will be conducted in accordance with the applicable POPs included in **Appendix D**. Field parameters will be collected for temperature, pH, dissolved oxygen, specific conductivity, and oxidation reduction potential.

#### 6.6 Investigation Derived Waste Management

All IDW produced during remediation and groundwater monitoring activities will be containerized and stored on-site in an appropriate location pending waste profiling and disposal coordination. All containers will be marked with weather resistant labels to identify the contents (drill cuttings, water, decontamination fluids, etc.), place of origin, and the date when the materials were initially placed in the container.

Soil cuttings are not expected during injection activities. However, any soil cuttings generated during the injection work described in this work plan determined to be impacted by petroleum hydrocarbons associated with historical exploration and production activities will be treated at the nearby WDEQ-permitted Encana soil composting facility. Groundwater generated during the groundwater sampling activities described in this work plan will be analyzed for waste characterization purposes. It is anticipated that all groundwater generated will be non-hazardous and will be disposed of at the Riverton, Wyoming Wastewater Plant, or another facility certified to receive the waste, in accordance with all applicable state and local regulations.

#### 6.7 Confirmation Sampling and Decommissioning

Confirmation of soil clean-up was accomplished immediately following the soil excavation and again confirmed during the 2011 investigation activities as described in Section 2.2. Confirmation of groundwater clean-up will be based on the groundwater monitoring results. Upon receipt of a certificate of liability assurance from the WDEQ, all groundwater monitoring wells will be plugged and abandoned in accordance with the WDEQ WQD rules and requirements.

## 6.8 Reporting and Data Evaluation

Reports on remedial progress will be prepared and submitted on an annual basis during the first quarter of each year until Site closure is obtained. The reports will include a summary of the work completed over the prior year, a presentation of the data collected, and an evaluation of the results. An evaluation will be conducted approximately 1 year following injection activities to estimate the remediation clean-up timeframe using MNA.

## 6.9 MW-6 Sampling and Abandonment

In March 2012, Encana requested approval from the WDEQ to plug and abandon Monitoring Well MW-6. This request was initiated because the property owner requested that the well be removed, if possible, due to its interference with farming operations. As stated in a letter from the WDEQ dated June 11, 2012, Monitoring Well MW-6 will be sampled when the static water level is similar to the September 2011 sampling event (WDEQ 2012b). The groundwater sample will be submitted for laboratory analysis of BTEX, TPH-GRO, and TPH-DRO. If all constituents analyzed are not detected in the groundwater sample above MCLs, then Encana will request to remove Monitoring Well MW-6.

Upon approval by the WDEQ, Encana will plug and abandon MW-6 in accordance with the WQD requirements as listed in Chapter 26 of the WQD rules and regulations. One abandonment report form will be submitted to the WQD following proper abandonment. A copy of the well Abandonment form is provided in **Appendix F**. The groundwater sampling of MW-6 will occur in the agricultural field located south of the Site. An Access Agreement will be prepared for access to this property prior to sampling this well.

## 6.10 Schedule

The anticipated schedule is based on similar work at other sites and may vary greatly depending on the effects of the remediation on the rate of biodegradation, site access, and other factors. The rate of biodegradation and corresponding schedule will be re-evaluated 1 year following the remediation injections. Following approval of the remedial alternatives evaluation and work plan, the work plan will be implemented as provided below.

- The receipt of appropriate permits and bioremediation injection activities will occur within approximately 3 to 6 months following approval of this work plan.
- Monthly groundwater sampling of remediation target wells WT-1-11, MW-2, and MW-4 will be conducted for 6 months following the bioremediation injections to evaluate the remediation effectiveness. Quarterly groundwater sampling will occur during the first year following injections to monitor post-remediation seasonal groundwater conditions. Semi-annual groundwater monitoring will be conducted following 1 year of quarterly groundwater sampling until performance objectives have been met.
- In accordance with Fact Sheet #26, semi-annual groundwater sampling will continue for a period of 1 year following the reduction of groundwater concentrations below clean-up levels to demonstrate long-term effectiveness of the remedial action (WDEQ 2007a). Once the demonstration of long term effectiveness has been met, Encana will submit a Site closure report and request a certificate of liability assurance (Fact Sheet #15) (WDEQ 2007b).
- Groundwater sampling of Monitoring Well MW-6 is scheduled for September 2012 to correspond with the September 2011 water levels in accordance with WDEQ's request.

## 7.0 References

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## Tables

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## Figures

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## **Appendix A**

### **Completed Field Forms From 2011 and 2012 Site Activities**

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## **Appendix B**

### **Laboratory Reports**

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## **Appendix C**

### **Trend Test Results**

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## **Appendix D**

### **Project Operating Procedures**

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## **Appendix E**

### **Oxygen Release Product Information**

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## **Appendix F**

### **Permit Forms**

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